

High efficiency LEDs by Photonic Crystal-assisted extraction

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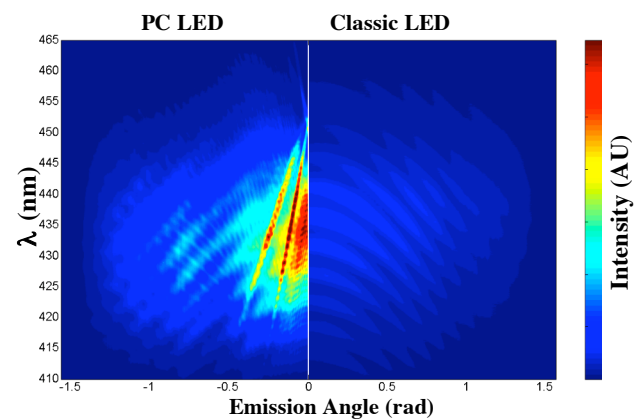
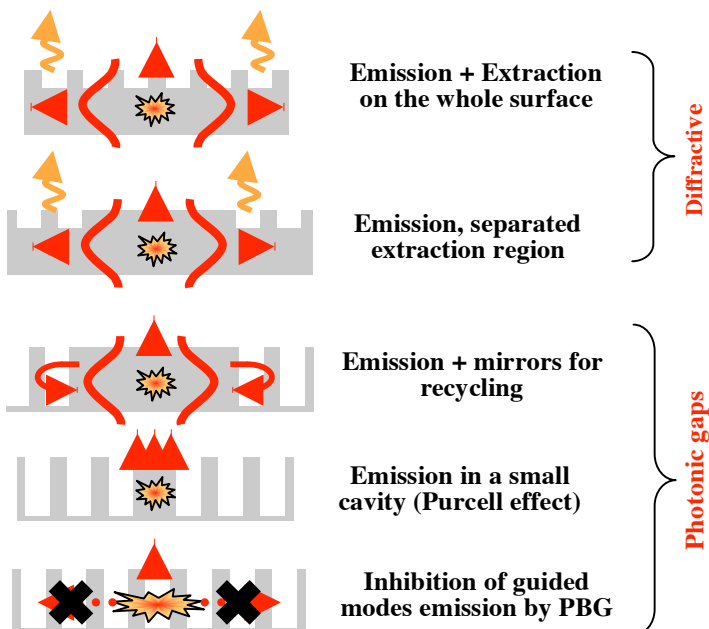
We are progressively approaching the physical limits of microcavity LEDs (MC-LEDs) for high brightness, high efficiency LEDs. They are promising high efficiency devices and they offer the very attractive prospect of full planar fabrication process. However, to compete with other high efficiency LED schemes, they need to approach or surpass the 50 % efficiency mark. We first explore the limits of planar MC-LEDs in both the GaAlInAsP and GaInAlN materials systems, and show that the single-step extraction limit is 40 % at best, with most of non-extracted light emitted into guided modes.

We then discuss the various Photonic Crystal (PhC) structures that have been proposed to control spontaneous emission, and possibly enhance it, starting with the pioneering paper of Eli Yablonovitch. Funneling emission in one or a few channels has not yet been demonstrated. Even suppressing or enhancing the overall rate in photoluminescence experiments still appears difficult, for a variety of reasons.

We will concentrate on extracting waveguided light. One uses PhCs as mirrors or diffracting elements, for a variety of purposes : in-plane microcavities, out-of plane scatterers, etc. We will show recent results on GaN based PhC LEDs. A detailed analysis of angular resolved emission patterns allows to determine the PhC dispersion curves, and the extraction efficiency for the various waveguided modes.

Optimal design of a PhC extractor is strongly dependent on the material. In GaAs for instance, simple PhCs appear to lack the omnidirectional extraction properties required. However, more rotation-invariant PCs like Archimedean tilings allow to obtain such extraction with added efficiencies already in the 10% range.

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Left : various schemes for PhC-assisted light sources

Top : Angular resolved spectra of a PhC LED versus a classic LED in GaN